4. Agricultural Water Use Management and Efficiency Improvements

This section presents the basis and background for estimating the magnitude of agricultural water conservation potential. These conservation estimates are based on computations of potential reductions of water application and irrecoverable losses. Values presented in this section represent potential reductions that are most likely to occur for future conditions regardless of the outcome of a CALFED solution (termed the No Action Alternative) as well as the incremental savings expected from a CALFED solution.

These estimates are intended to provide a perspective of the order of magnitude of the potential effects of water use efficiency improvements both with and without the CALFED solution. The values presented are not goals or targets. Rather, they represent the relative magnitude of potential results of expected efficiency actions.

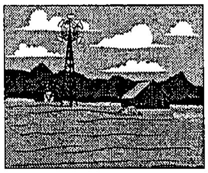
Stakeholders disagree on the magnitude and the feasibility of achieving these values. In response, CALFED convened an Independent Review Panel of Agricultural Water Conservation (Panel) in December 1998, to provide an unbiased scientific evaluation of this section.

The Panel agreed that the values contained here are acceptable preliminary estimates of conservation potential. They also made several valuable recommendations for refining these estimates and strengthening the methodology. These recommendations included presenting estimates of evaporation reduction potential. The Panel's recommendations will be included in a refinement of these estimates, which will be conducted during the first years of Stage 1.

This section includes the following estimates:

- Potential reductions in agricultural water losses expected for each of the nine geographic regions described in Section 3.

- Expected costs of reducing agricultural water losses



4.1 SUMMARY OF FINDINGS

Improvements in on-farm and district water management can result in the reduction of losses typically associated with the application of irrigation water to fields. Though the majority of loss reduction does not generate a water supply available for reallocation to other beneficial uses, significant benefits to water quality and the ecosystem can be obtained as well as potential in-basin water supply benefits. Conservation estimates are separated into three categories:

- ***Recovered losses with potential for rerouting flows*** - These losses currently return to the water system, either as groundwater recharge, river accretion, or direct reuse. Reduction in these losses would not increase the overall volume of water but might result in other benefits, such as improving water quality, decreasing diversion impacts, improving flow between the point of diversion and the point of return, or potentially making water available for irrigation or in-stream flows during dry periods. (See Section 4.4, "Irrecoverable vs. Recoverable Losses.")

- ***Potential for recovering currently irrecoverable losses*** - These losses currently flow to a salt sink, inaccessible or degraded aquifer, or the atmosphere and are unavailable for reuse. Reduction in these losses would increase the volume of useable water (reducing these losses can make water available for reallocation to other beneficial uses). (See Section 4.4, "Irrecoverable vs. Recoverable Losses.")

- ***Potential reduction of application*** - This is the sum of the previous reductions.

Based on the assumptions and data described later, the conservation estimates are shown in Figures 4-1, 4-2, and 4-3.

Although the total potential loss reduction estimates shown here are sizable, it must be recognized that they assume that **all** agricultural water users in the CALFED solution area will achieve a high level of on-farm irrigation efficiency improvements. This achievement will require increased levels of support and commitment from federal, state, and local agencies.

Costs associated with implementing improvements to achieve these loss reductions will vary by case. Both on-farm and district spending are necessary to obtain the anticipated levels of improvement. Generally, the on-farm cost to reduce losses ranges from \$35 to \$95 per acre-foot annually. District expenses can add an additional \$5 to \$12 per irrigated acre per year to the cost of improved efficiency. In contrast, the range of cost to conserve irrecoverable losses is much greater because in many cases only a small fraction of total loss is irrecoverable (see Figure 4-4). When reductions in irrecoverable losses do occur, the cost is estimated to range from \$80 up to \$850 per acre-foot per year. A detailed discussion of cost is provided toward the end of this section.

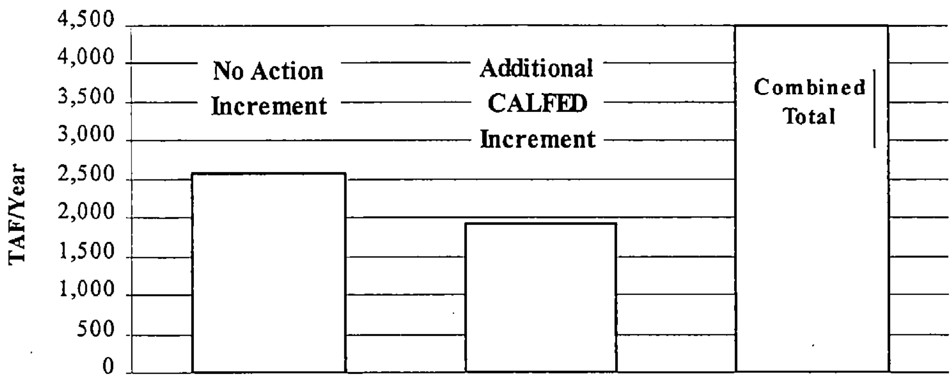


Figure 4-1. Potential Reduction of Application
These reductions are the sum of reductions shown in Figures 4-2 and 4-3.

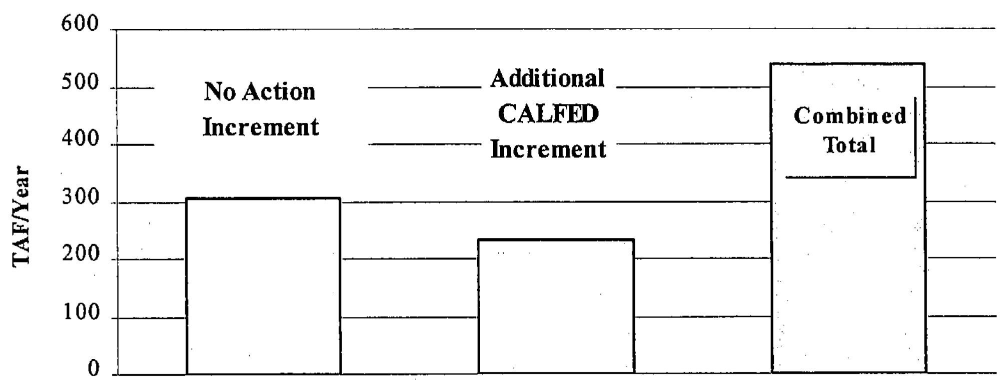


Figure 4-2. Potential for Recovering Currently Irrecoverable Losses
The incremental portion generated by CALFED is less than half of the total projected savings. This savings can be reallocated to other beneficial uses.

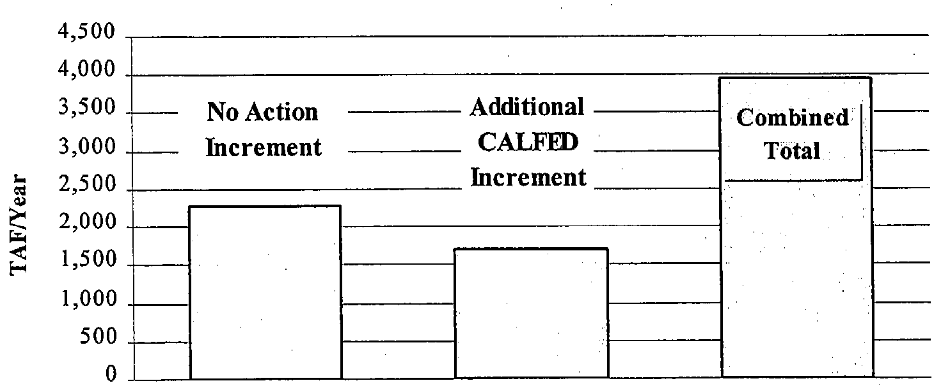


Figure 4-3. Recovered Losses with Potential for Rerouting Flows
These reductions can provide water quality and ecosystem benefits. The reductions do not constitute a reallocable water supply but can reduce projections of future demand.

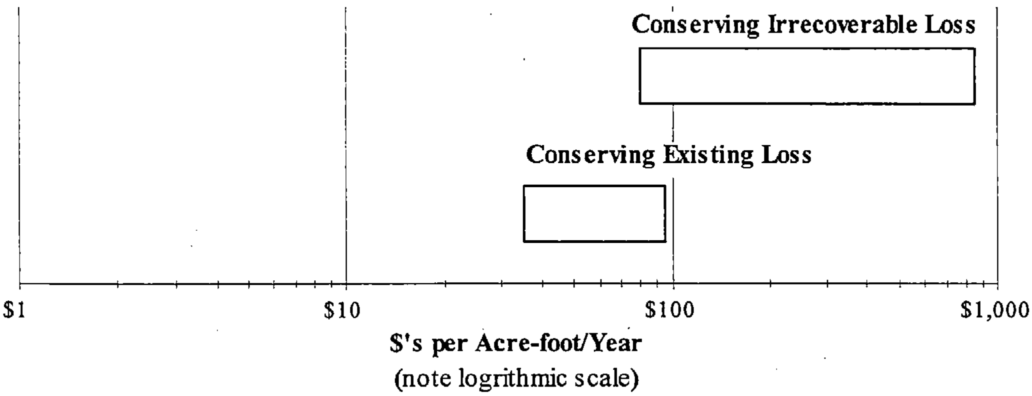


Figure 4-4. Estimated Cost to Conserve Existing Losses
Conserving irrecoverable losses can cost significantly more than reducing recoverable losses.

These costs will occur only when cost-effective conservation measures are implemented. There is no implied assumption that these costs will be incurred regardless of cost-effectiveness determinations. Furthermore, it should be understood that these costs are associated with the implementation and do not designate who is paying. In some cases, state or federal interests may invest in local programs, in an effort to achieve broader water quality, ecosystem, or water supply benefits.

SECTION OVERVIEW

The remainder of this section provides more detail on the assumptions and methods underlying the conservation estimates. The section is subdivided into the following topics:

- General state-wide assumptions.
- Discussion of on-farm irrigation and district delivery efficiency improvements.
- Irrecoverable versus recoverable losses—including differentiation of the two types of losses and the benefits that can be derived from each.
- Methodology for estimating agricultural water conservation potential.
- Regional reduction estimates—including descriptions and assumptions for each defined CALFED agricultural region and the resulting conservation estimates.
- Estimated cost of efficiency improvements—including the cost to implement efficiency improvements for each agricultural region.

4.2 GENERAL STATE-WIDE ASSUMPTIONS

It is important to note that these estimates are presented to help understand the potential role conservation could play in the larger context of state-wide water management, as well as to provide information for purposes of programmatic-level impact analysis. **These estimates are not targets or goals and should not be interpreted as such.** Neither the information nor the analysis is intended to be used for planning recommendations.

The general state-wide assumptions listed below helped guide the overall analysis and development of conservation estimates. Specific assumptions are described later in this section.

- It is assumed that irrigated agricultural acreage will not increase in the future. Statewide, agricultural acreage is expected to decline as a result of Central Valley urbanization, loss of soil productivity, ecosystem restoration activities, land retirement, water transfers, and other factors (DWR Bulletin 160-93). Because such uncertainties are difficult to project, conservation estimates are based on current irrigated acreage using normalized 1995 data on agricultural water use.

- Conservation of water that results in additional water supply available for reallocation to other beneficial water supply uses is limited to the reduction in currently irrecoverable losses. These include losses to evaporation, evapotranspiration of nonagricultural plants, saline sinks, and poor-quality perched groundwater. (This topic is discussed later in this section.) Although other changes in farm management also would reduce consumptive water use by agriculture, only conservation of applied water is discussed. These other measures include changes in crop mix, fallowing, and permanent land retirement and are explicitly not included in the Water Use Efficiency Program. (These measures could occur, though, as a result of actions taken by individual water rights holders through the Water Transfer Program.)

> **GENERAL STATE-WIDE ASSUMPTIONS**
>
> - Agricultural acreage will not increase in the future.
> - Conservation of water that results in additional water supply available for reallocation to other beneficial water supply uses is limited to the reduction in currently irrecoverable losses.
> - Water conservation actions that reduce currently recovered losses (the portion of loss that is not defined as irrecoverable) potentially can be credited with ecosystem or water quality benefits and could reduce the magnitude of future demand.
> - Conserved water (either by a water district or a water user) will remain in the control of the supplier or water user for their discretionary use or reallocation.

- Water conservation actions that reduce currently recovered losses (the portion of loss that is not defined as irrecoverable) potentially can be credited with ecosystem or water quality benefits and could reduce the magnitude of future demand in a region. However, such savings generally do not result in water that can be reallocated to other uses. Since these losses currently benefit other downstream uses (agricultural, urban, or environmental), the potential exists for adverse impacts to occur when existing irrigation methods are changed. This potential needs to be taken into consideration when implementing efficiency measures. These benefactors can include secondary agricultural users, seasonal wetlands, and riparian habitat in drains, to name a few. For example, a measure to reduce diversions and associated fish entrainment impacts by implementing conservation measures may adversely affect habitat in a drainage course that currently survives off of the "excess" applied water.

- Conserved water (either by a water district or a water user) is assumed to remain in the control of the supplier or water user for their discretionary use or reallocation. This could include applying the "saved" water to additional under-irrigated lands; offsetting groundwater overdraft; or transferring to another benefactor, including the environment. (Transferring water requires additional legal tests to be satisfied.)

When discussing the ability to achieve implementation of conservation measures, not only the technical capacity to improve water management should be considered. From the viewpoint of the landowner, who is a business operator, many factors are considered in addition to the single factor of water conservation. In many instances, a landowner may not see the value of investing in improved levels of efficient use because of insufficient return on the investment. In other instances, landowners justify the expense of improving their irrigation systems through increased yields, better quality, and reduced inputs. In regions where water supplies are less reliable and usually more expensive, improved management and irrigation techniques can be cost effective for the primary reason of the reduced cost of supplying water to the crop. For a grower, the decision to spend capital is generally made when the capital will be returned over a relatively short period of time. Several forms of repayment are possible—from reduced labor, chemical, and water costs, to improved yields per acre.

Social issues also play a role in the decision to implement new measures. For example, some growers use field laborers not trained in irrigation management to irrigate rather than a specially trained irrigator. The operation of a more management-intensive irrigation system may intimidate some irrigators. Although these issues exist and will be a factor in the rate of acceptance and implementation, they are not assumed to limit the values projected here.

4.3 DISCUSSION OF ON-FARM AND DISTRICT EFFICIENCY IMPROVEMENTS

The discussion that follows provides background and justification for assumptions made later in this section regarding levels of conservation expected in the future. On-farm irrigation and district delivery are discussed for the following:

- Existing conditions.
- The No Action Alternative, which includes conditions expected with implementation of some on-farm irrigation and district delivery improvements.
- The CALFED solution alternative, which includes projections of future conditions that could exist as a result of implementing the Water Use Efficiency Program.

4.3.1 IMPROVING ON-FARM IRRIGATION EFFICIENCY

As defined by DWR for the Bulletin 160 series, **irrigation efficiency is defined as the volume of irrigation water beneficially used, divided by the volume of irrigation water applied.** Beneficial uses include crop evapotranspiration (ET), water harvested with the crop, salt removal (leaching), cultural practices, climate control, and other minor activities (Burt et al.). Given these various elements and the difficulty in accurately measuring any one of them, it should be noted that efficiency is a gross measurement. Efficiency values are estimates based on best scientific data and should be viewed as a tool to help make management decisions. The information itself can easily be misinterpreted or may be incomplete, resulting in an estimate of efficiency that is not accurate. For example, not including in the total applied water value a crop's uptake of irrigation water previously stored in the soil can make efficiency appear higher than it actually is.

On-farm irrigation efficiency, in more practical terms, is a complex result of the type of irrigation system, the level of irrigation management, the amount of irrigation system maintenance, the method of delivery to the field, the timely availability of water, the climate, the soil, the crop, the irrigator, and many other factors. Efficiency does not improve simply by changing one of these factors. In fact, some studies have shown that efficiency can worsen when, for example, a system type is changed but the management style is not. High levels of irrigation efficiency that are sometimes referred to by agriculture, by the public, and by policy makers can be misleading since they may reflect regional, miscalculated, or one-time efficiencies and not the average annual efficiency of a particular irrigation practice. In some instances, these high efficiency values mean that the crop actually is being under-irrigated (although it is possible to use 100% of the applied water beneficially and still under-irrigate, it is not possible to use more than 100% of the applied water; thus, efficiency can never be greater than 100%). Under-irrigation can lead to reduced yields and the possibility of salt buildup in the soil.

It is important to distinguish between on-farm irrigation efficiency and regional efficiency. Regional efficiency is derived from a combination of on-farm efficiencies and the level of regional water reuse, including reuse of deep percolation and tailwater runoff. It is erroneous to draw a comparison between regional efficiency and on-farm efficiency without considering regional reuse, a primary reason for higher regional efficiencies. For example, water lost from one field as tailwater runoff or deep percolation, if water quality is not severely degraded, can be reused on another field for additional beneficial uses. The greater the level of reuse, regardless of the on-farm efficiency of any particular field, the higher the regional efficiency will tend to be.

Existing On-Farm Efficiency Levels

Analysis of over 1,000 different field evaluations of on-farm irrigation systems shows that state-wide on-farm irrigation efficiency is averaging nearly 73% (DWR 1992). However, the value can vary significantly from farm to farm, basin to basin, and region to region.

Generally, this value should be viewed as a guide, indicating the approximate conditions that may exist on many farms throughout the state. As discussed later, the amount of total loss derived from applied water and crop consumption data for each region dictate the resulting conservation estimates to a much greater extent than does an existing irrigation efficiency value. This is because the existing efficiency, or baseline, is used simply as a point of reference from which to judge progress toward improved efficiency. We can safely assume that the available efficiency improvement lies somewhere between the existing condition and 100%.

Projected Average On-Farm Efficiency under the No Action Alternative

Average on-farm irrigation efficiency is anticipated to improve as a result of existing trends in growers' irrigation systems and management, coupled with improved district delivery systems (covered in the next subsection). The level of improvement is a matter of judgement. CALFED has assumed, for purposes of estimating incremental conservation improvements, that 40% of the potentially conservable water is saved under the No Action Alternative (more detail is provided later in this section).

Efforts by federal, state, and local agencies over the past decade in research and education are expected to continue to provide new understanding of plant/water/soil relationships that will aid in improving water management. In addition, the renewed focus on conservation and approval of new funding sources, such as Proposition 204, will continue to influence efficiency improvements. Consequently, for the CALFED No Action Alternative, on-farm efficiency is projected to be higher than it is today. Estimates of what may occur are presented here to differentiate between what is projected under the No Action Alternative, absent the CALFED Program, and what additional improvements may result from implementing the Water Use Efficiency element. This difference provided the basis for programmatic-level analysis of the impacts of the Water Use Efficiency Program.

One of the factors that limits projected efficiency improvements is termed "distribution uniformity." Distribution uniformity (DU) is the uniformity with which irrigation water is distributed to different areas in a field (Burt et al.). DU is affected primarily by five factors:

- System manufacturing (nozzle size, material durability, and performance reliability),
- System design (number of emitters per tree, spacing of sprinklers, and size and spacing of furrows),
- System maintenance (nozzle replacement, land grading, and drip system chlorination),
- System management (how well a grower operates the system in comparison to the needs of the crop), and
- Local physical and environmental conditions (soil, terrain, and climate).

Most experts in the field of irrigation maintain that current hardware design and manufacturing technology, as well as typical system maintenance activities, limit the DU to a ratio of 0.8 (80% of the field will be irrigated to the desired depth, while 20% will not). The anticipated efficiency improvements under the No Action Alternative assume that the majority of irrigators will be able to obtain this level of DU with their irrigation systems. This level is necessary to achieve higher average on-farm efficiencies without significant under irrigation. Because of the relationship of DU to efficiency, significant increases in on-farm efficiency is unlikely without accompanying improvements in DU, especially if soil conditions are to be maintained for optimum crop production.

Additional Efficiency Improvements as a Result of the CALFED Program

The CALFED Program's Water Use Efficiency component is expected to gain additional increments of on-farm irrigation efficiency improvements. These gains will be facilitated by increased levels of technical, planning, and financial assistance, along with improved district delivery systems (covered in the next subsection).

To allow average on-farm efficiencies to increase such that more than 40% of the potentially conservable water is saved requires that DU increase to a range of 0.8-0.9. Analysis of data indicates that an increase of DU to this range for example, can result in applied water reduction of 8-12% (for example, about a 3-4 inch reduction in applied water on a crop like tomatoes) without any reduction in crop water requirement or any reduction in beneficial uses (DWR 1990-1996). Such improvements could occur through advances in design and manufacturing of pressurized hardware, along with increase awareness and implementation of irrigation system maintenance. Figure 4-5 shows relationships between applied water, irrigation efficiency, and improved DUs. Note that, as the figure demonstrates, reductions in applied water occur solely as a result of increased DU, without reductions in beneficial use (such as crop consumptive use, leaching, and climate control).

This improvement can occur as a result of combined efforts to improve manufacturing processes and system designs, and from efforts by irrigators in improving maintenance and management practices for irrigation systems. It is reasonable to expect these improvements to occur because of increased awareness and necessity for higher efficiency resulting from the CALFED Program and response by the irrigation industry.

With a higher potential DU, incremental on-farm efficiency improvements above No Action Alternative levels can be assumed for each agricultural region. To estimate conservation potential, CALFED has assumed that the next 30% of available conservable supply (beyond the initial 40% achieved under the No Action Alternative) will be saved as a result of Water Use Efficiency Program actions. However, it must be recognized that this amount is assumed as a maximum level for maintaining optimum crop production. Gains that exceed this level could indicate widespread under-irrigation, salt accumulation in the soil, and lower crop yields per unit of applied water rather than actual improvements in the overall use of the water. In some instances, climate, soil, and cropping conditions on particular fields may allow even greater efficiencies to be achieved, but only to a nominal extent when compared to the average farming condition throughout the state.

For clarification, it is assumed the average on-farm irrigation efficiency will achieve the following gains:

No Action Alternative = First 40% of the potential conservable supply
CALFED alternative = Next 30% of the potential conservable supply

Detailed discussion of the methodology used to calculate conservation potential is presented in Section 4.7, "Estimating Agricultural Water Conservation Potential."

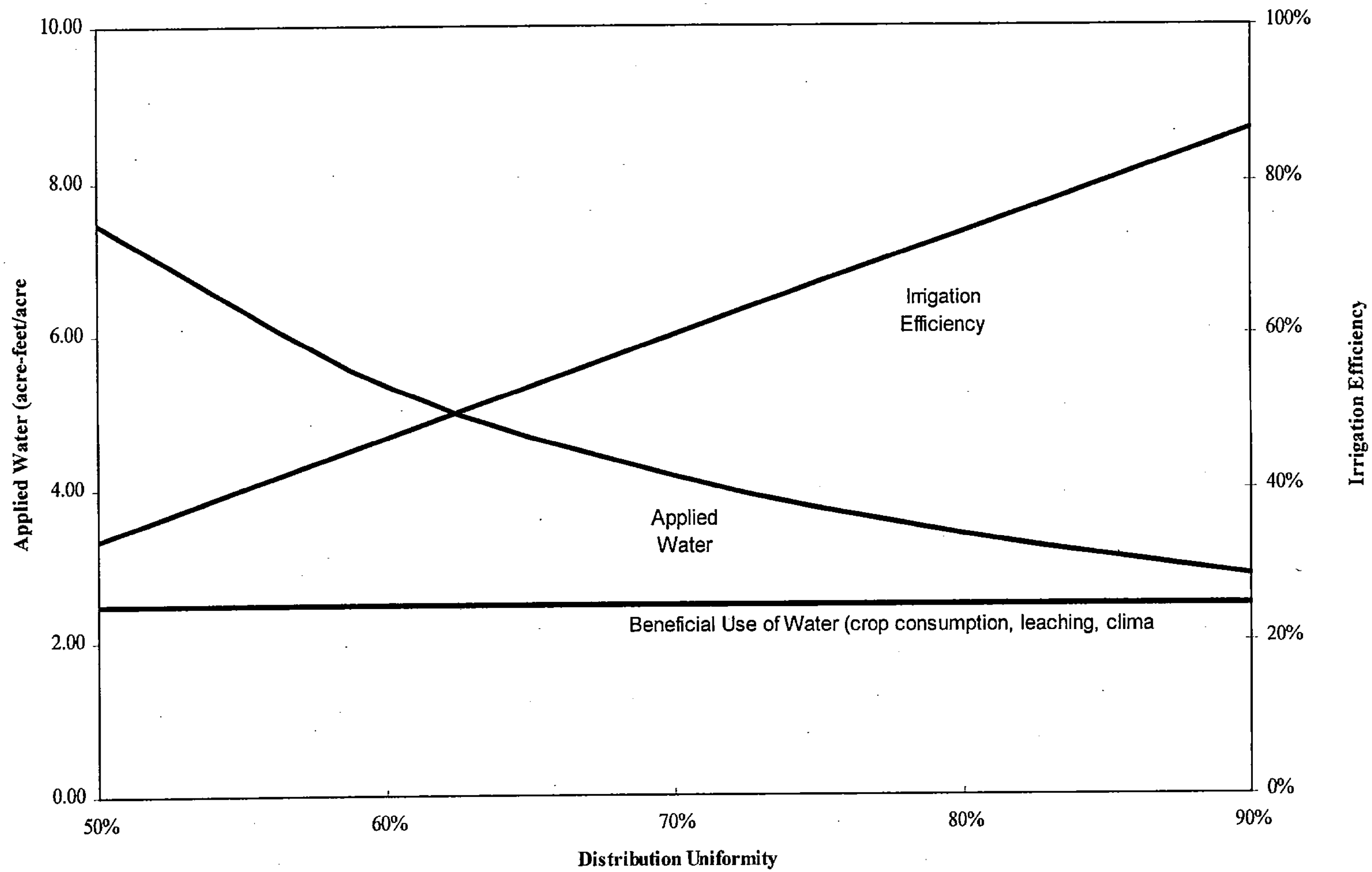


Figure 4-5. Effect of Improved Distribution Uniformity on Potential Seasonal Irrigation Efficiency and Applied Water

Improvements in distribution uniformity can result in increased efficiency and decreased applied water while still meeting beneficial crop needs.

Figure courtesy of DWR